Short Description of Bluetooth

Good judgment comes from long experience.
Long experience comes from exercising bad judgment.

Harald Bluetooth was a viking chieftain, named for his dark complexion, and not for any miss-colored tooth, as might be suspected. His real name was **Harald Gormsson**. He was king of Norway and Denmark during the 10th century. He waged war against Germany and managed to gather a huge armada of viking ships, whose crews almost overran northern Germany. Harald Bluetooth converted to Christianity and lived a very adventurous life. He was ultimately deposed in a coup, and died in exile. There is a more extensive biographical note at the end of this essay, if you are interested.

For those who like to experiment with Bluetooth, Ericsson Mobile Communications has produced 2 Bluetooth Kits:

- An application tool kit and
- A development kit.

Bluetooth is a by now well-established communications standard for **short-distance wireless** connections. It replaces the many proprietary cables that connect one device to another with **one** universal short-range **radio link.** For instance, Bluetooth radio technology built into both the cellular telephone and the laptop would replace the cable used today to connect a laptop to a cellular telephone. Printers, desktops, fax machines, keyboards, joysticks and

Since Bluetooth is an open standard, there is plenty of detailed information to be found on the Bluetooth website. We have nevertheless choosen to present a brief description here, so that the pages detailing **FLYWAYs** use of Bluetooth will be easier understood. If one starts to read the detailed PDF-files on the Bluetooth website, describing every aspect of this technology, one might be stuck all day, just reading.

List of contents:

See the next page for some Bluetooth abbreviations & acronyms, and the

	virtually any other digital device can be part of the Bluetooth system. The Bluetooth radio technology also provides a universal bridge to **existing** data networks, a peripheral interface, and a mechanism to form small private ad hoc groupings of connected devices away from fixed network infrastructures. The work with development of Bluetooth was started by **Ericsson Mobile Communication** in 1994. It is ideally suited to **FLYWAYs** need for a functional interface between travelers and the system. It could also be used in communication with the beamcars. These 2 uses are described on two separate webpages; **"Using Bluetooth as Passenger Interface"** and **"Using Bluetooth as**	Bluetooth profiles.

Beamcar Interface".

1. Bluetooth´s background and competition

n 1995, the telecommunications and information technology industries recognized that a low-cost, low-power radio based cable replacement, or wireless link, would be feasible, thus eliminating the need for communication cables for short distances. Such a ubiquitous link would provide the basis for small portable devices to communicate together in an ad-hoc fashion.

A study was done, and the technology, code named **"Bluetooth",** was soon defined. The goal was to provide reliable service for mobile and business users by means of a small, short range radio-based technology. This would be integrated into production line models of a range of different devices.

Surfing on the CyberShuttle

The University of California at San Diego has introduced a **shuttle bus** they call the CyberShuttle that allows passengers to surf the Web and send e-mail. The bus connects the university campus with a commuter train station, a 30-minute round trip that many students take daily. The CyberShuttle combines 802.11b technology with a product developed by Qualcomm known as **3G broadband**. These two technologies are generally considered incompatible, but researchers at the university were able to make the two work together, providing service comparable to DSL or a cable modem while on a bus traveling 65 mph. Chronicle of Higher Education, 2 April 2002.

The 802.15.1 Standard

The Institute of Electrical and Electronic Engineers (IEEE) has developed and approved a new wireless standard, 802.15.1, that is **fully compatible** with Bluetooth. As with Bluetooth, the new standard has a smaller transmission range and lower speed than the 802.11 standard, although both standards run in the 2.4 GHz range. The IEEE Std 802.15.1™-2002 standard is an additional resource for those who implement Bluetooth devices.

The lower transport layers (L2CAP, LMP, Baseband, and radio) of the Bluetooth™ wireless technology are defined. Also specified is a clause on SAPs which includes a LLC/MAC interface for the ISO/IEC 8802-2 LLC. Also specified is an normative annex which provides a Protocol Implementation Conformance Statement (PICS) proforma. Also specified is a informative high level behavioral ITU-T Z.100 Specification and description language (SDL) model for an integrated Bluetooth MAC Sublayer.

The 802.15.1 standard is supported by the Bluetooth Special Interest Group, which receives support from 3Com, Nokia, Intel, and other wireless industry stalwarts.

Why not use Infrared transmission/reception?

Some readers may wonder why a new short-distance, wireless communication standard, such as Bluetooth, is necessary, when there is **IrDa,** a transmission technique which is used primarily in remote controls. The Infrared Data Association (IrDA) specifies three infrared communication standards: **IrDA-Data, IrDA-Control,** and a new emerging standard called **AIr.** For our comparative purposes, it´s the IrDA-Data-standard that would apply.

Well, IrDa has its advantages, but it is not quite up to **our** task, for various reasons. Primarily, IrDa is point-to-point, it´s very directional, it won´t transcend opaque materials, etc. We won´t delve further into this matter here, but a comparison of these 2 systems can be found at the **Extended Systems Inc.** website.

Why not use Airport?

"Airport" is a wireless communications system, which, like Bluetooth, is based on the IEEE 802.11 recommendation. It also uses 2.4 GHz frequency band, but its range is about 45 meters and it boasts a transmission speed of 11 Mbit/second. It is developed by Lucent Technologies and used with **Apples** MacIntosh, and not

Why not use Wireless LAN?

Wireless LAN-technology (WLAN) might sound like an alternative to Bluetooth. Well, they are both based on the same communications standard (**IEEE 802.11**) and use the same frequencies for carriers. But there the similarities end. WLANs use ordinary LAN protocols for communication; not so Bluetooth, because Bluetooth is not meant for LAN-communications. Nor is Bluetooth meant for transmitting huge amounts of data, as are LANs and WLANs.

Bluetooth puts its emphasis on dynamically handling mobile units of various kinds.

Why not use UWB?

Ultra-wideband (**UWB**) transmission, if approved by the FCC, could lead to the development of technology with throughput capacity far superior to 802.11b wireless LANs. In turn, 802.11b and short-wave Bluetooth radios could be replaced with UWB products that offer lower costs, higher bandwidth, and greater user support.

UWB transmissions do not involve carrier signals, and thus eliminate waveband crowding. Furthermore, UWB transmitters and receivers have relatively few construction, operational, and maintenance needs. The power requirements are also quite small, in the 50- to 70-

Why not use Wi-Fi?

Wi-Fi" is the name of a similar, but simpler, technology, based on **802.11b.** Wi-Fi is an open-standard technology that enables wireless connectivity between laptops and local area networks. Today's Wi-Fi products, which transmit in the unlicensed spectrum at 2.5 GHz, are capable of speeds of up to 11 Mbps, which is about seven times faster than a typical T1 connection.

Bluetooth and other home LAN protocols have superior technologies, but don't be fooled. The history of technology has repeatedly shown that if a certain open architecture gains escape velocity, it will corner the market. The cost declines brought on by ramping up unit volumes alone are enough to thwart any competitive threat.

Wi-Fi has all the makings of a pervasive, explosive technology: huge growth, a strong value proposition, multiple and expanding uses, industry standardization, and global standardization. The technology's flaws are nothing more than a speed bump, given the billions of dollars of R&D already poured into this space. But in certain applications, nothing can replace the more advanced Bluetooth protocol.

Microsoft has **not** added

much details are published about it, compared to the completely open Bluetooth. Apparently, it is only available in small modules for interconnection between Apple compatible equipment and the Internet. It seems clear, however, that Airport does not have the sophisticated protocols that Bluetooth has.

Airport thus cannot be of use for **FlyWay´s** vehicle communications. The longe range of Airport can be obtained (and superseeded) by Bluetooth. Possibly can the 11 Mbit/second transmission speed be of use to passengers in the cars.

milliwatt range. In addition, since pulse signals blend so easily into background electronic noise, UWB transmissions are well protected.

Ultra Wide Band is a wireless communications technology that can currently transmit data at speeds between 40 to 60 megabits per second and eventually might come up to 1 gigabit per second. UWB transmits ultra-low power radio signals with very short electrical pulses, often in the picosecond (1 millionth of a second) range, across **all** frequencies at **once.** UWB receivers must translate these short bursts of noise into data by listening for a familiar pulse sequence sent by the transmitter.

UWB has low power requirements, and is therefore very difficult to detect and thus difficult to regulate. Because it spans the entire frequency spectrum (licensed and unlicensed), it can be used indoors and underground, unlike GPS.

There are worries that UWB devices operating below 2 GHz will break into global positioning system, air traffic, television, and other broadcasts. There is also the question whether UWB will support all the higher protocols included in Bluetooth.

You can read more about UWB **here.**

Bluetooth capabilities to its newest version of Windows XP, but instead included Wi-Fi support. Although Wi-Fi requires that users be within the proximity of a transmitter, it offers faster speeds and easy adaptation for programs because it so closely resembles traditional networking. In contrast, Bluetooth would allow devices to communicate directly with one another instead of going through a transmitter.

2. The IEEE 802.11 Standard

luetooth is based on the **The IEEE 802.11 standard,** as is Lucent Technologie´s "Airport", WLAN and other wireless communications standards. This standard defines the protocol for **two** types of networks; **Ad-hoc** and **client/server** networks.

An Ad-hoc network is a simple network where communications are established between multiple stations in a defined coverage area, without the use of an access point or server. The standard specifies the etiquette that each station must observe so that they all have fair access to the wireless media. It provides methods for **arbitrating** requests to use the media to ensure that throughput is maximized for all of the users.

The client/server network uses an **access point** that controls the allocation of transmit time for all stations, and allows mobile stations to roam from cell to cell.

The **access point** is used to handle traffic from the mobile radio to the wired or wireless backbone of the client/server network. This arrangement allows for point coordination of all of the stations in the basic service area and ensures proper handling of the data traffic. The access point routes data between the stations and other wireless stations or to and from the network server.

We have devoted a separate page for a description of this recommendation. See **"The 802.11 recommendation"**

3. Technological characteristics

he stated aim with developing the Bluetooth standard was to arrive at a specification for a technology that optimizes the usage model of **all** existing mobile computing and communications devices, and providing:

1. Global usage
2. Voice and data handling
3. The ability to establish ad-hoc connections
4. The ability to withstand interference from other sources in open band
5. Very small size, in order to accommodate integration into variety of devices
6. Negligible power consumption in comparison to other devices for similar use
7. An open interface standard
8. Low cost

Bluetooth is specifically designed to provide low-cost, robust, efficient, high capacity, ad hoc voice and data networking with the following characteristics:

1. **1** Mb/sec. transmission/reception rate that exploits maximum available channel bandwidth.
2. Fast frequency hopping to avoid interference.
3. Adaptive output power to minimize interference.
4. Short data packets to maximize capacity during interference.
5. Fast acknowledge, which allows low coding overhead for links.
6. **CVSD** (Continuous Variable Slope Delta Modulation) voice coding, which enables operation at high bit-error rates.

7. **F**lexible packet types that supports a wide application range.
8. **R**elaxed link budget that supports low-cost single chip integration.
9. **T**ransmission/reception interface tailored to minimize current consumption.

These features will enable Bluetooth to provide extremely flexible and high data rate links even in the presence of severe interference. In addition to performing well when signal conditions are good, as the interference increases the performance degradation will remain minimal and gradual, enabling stable links to be maintained.

Bluetooth is a Radio Frequency (RF) specification for short-range, point-to-multipoint voice and data transfer. Bluetooth can transmit through solid, non-metal objects. Its nominal link range is from 10 cm to 10 meters, but can be extended to 100 meters by increasing the transmit power. It is based on short-range radio links, and facilitates ad hoc connections for stationary and mobile communication environments.

4. Technical Information

Figure 4:1

Figure 4:2

General

luetooth technology has been designed to operate in **noisy** radio frequency environments, and uses a fast acknowledgement and frequency-hopping scheme to make the link robust, communication-wise. Bluetooth radio modules avoid interference from other signals by hopping to a new frequency after transmitting or receiving a packet. Compared with other systems operating in the same frequency band, the Bluetooth radio typically **hops faster** and uses **shorter packets**. This is because short packages and fast hopping limit the impact of microwave ovens and other sources of disturbances. Use of Forward Error Correction (FEC) limits the impact of random noise on long-distance links.

The Bluetooth baseband protocol is a **combination** of **circuit** and **packet** switching. Time slots can be reserved for synchronous packets. A frequency hop is done for each packet that is transmitted. A packet nominally covers a single time slot, but can be extended to cover up to five slots. Bluetooth can support an asynchronous data channel, up to three simultaneous synchronous voice channels, or a channel which simultaneously supports asynchronous data and synchronous voice.

2 Power Levels

The Bluetooth specification has two power levels defined; a lower power level that covers the shorter personal area within a room, and a higher power level that can cover a medium range, such as within a home. Software controls and identity coding built into each microchip ensure that only those units preset by their owners can communicate.

Power Saving: the HOLD MODE

The ACL link of a connection between two Bluetooth devices can be placed in hold mode for a specified hold time. During this time no ACL packets will be transmitted from the master. The hold mode is typically entered when there is no need to send data for a relatively long time. The transceiver can then be turned off in order to save power. But the hold mode can also be used if a device wants to discover or be discovered by other Bluetooth devices, or wants to join other piconets. What a device actually does during the hold time is not controlled by the hold message, but it is up to each device to decide.

Dynamical Regulation of Transmitted Power

If the RSSI value (which is a measurement of transmitting antenna power) differs too much from the preferred value of a Bluetooth device, it can request an increase or a decrease of the other device’s TX (i.e. transmitted) power. Upon receipt of this message, the output power is increased or decreased one step. At the master side the TX power is completely independent for different slaves; a request from one slave can only effect the master’s TX power for that same slave.

Functional parts of the Bluetooth system:

- a radio unit
- a link control unit
- link management
- software functions

Definitions used

- **Piconet:** a collection of devices connected via Bluetooth technology in an ad hoc fashion. A piconet starts with two connected devices, such as a portable PC and cellular phone, and may grow to eight connected devices (see figure 4:1 above; that´s why the required address-space is limited to 3 bits). All Bluetooth devices are **peer units** and have identical implementations. However, when establishing a piconet, one unit will act as a master for synchonization purposes, and the

		other(s) as slave(s) for the duration of the piconet connection. • **Scatternet:** Two or more independent and non-synchronized piconets that communicate with each other. As shown in figure 4:2 above, a **slave** as well as a **master** unit in one piconet can establish this connection by becoming a slave in the other piconet. • **Master unit:** the device in a piconet whose clock and hopping sequence are used to synchronize all other devices in the piconet. • **Slave units:** all devices in a piconet that are not the master (up to 7 active units for each

		master). • **Mac address:** a 3-bit **M**edia **A**ccess **C**ontrol address used to distinguish between units participating in the piconet. • **Parked units:** devices in a piconet which are synchronized but do not have MAC addresses. • **Sniff and hold mode:** devices that are synchronized to a piconet, and which have temporarily entered power-saving modes in which device activity is lowered. • An **Ad-hoc network** is a simple network where communications are established between multiple stations in

a given coverage area without the use of an access point or server.

Technical Specifications

he Bluetooth air interface is based on a nominal antenna power of 0 dBm. Spectrum spreading has been added to facilitate optional operation at power levels up to 100 mW worldwide. It is accomplished by frequency hopping in 79 hops displaced by 1 MHz, starting at **2.402 GHz** and stopping at **2.480 GHz.** Due to local regulations, the bandwidth is reduced in Japan, France and Spain. This bandwidth reduction is handled by an internal software switch. The maximum frequency hopping rate is 1600 hops/s.

Transmission/Reception characteristics

The nominal link range is 10 centimeters to 10 meters, but can be extended to more than 100 meters by increasing the transmit power.

Number of channels: **79**
Channel division: 1 MHz
Transmission speed: 1 Mbit/sec.
Modulation: 2-level FSK
Modulation index: 0.32 (0.28 - 0.35) +/- 160 kHz
Frequency deviation: +/- 165 kHz

Receiver: RX sensitivity, -70dBm, IP 3, -16dBm, CP 1 dB, -6dBm
Double-sided IF bandwidth,
1.0MHz, C/I co-channel (0.1% BER),
11dB, C/I 1MHz (0.1% BER),
-8dB, C/I Š 2MHz (0.1% BER),
-40dB, C/I AWGN (0.1% BER),
18 dB, In-band image rejection, 20 dB.

Transmitter: TX power: nominal 0 dBm, optional range, -30 - +20 dBm
Modulation index (no ISI) 0.28-0.35, TX carrier

For the curious: the technique for long-range communication

Although Bluetooth is meant for short-range communication, it is quite permissible to increase the range to 100 meters. Considering the tolerance levels for background noise (and a receiver sensitivity of -70 dBm), the output power from an omni-directional transmitter would need to be 100 mW. This transmission power is classed as "Class 1", and is specified in "Radio Specification" in the Bluetooth-spec., ver. 1.0, ref. 2.

This specification also mandates that the transmitter has an **effect regulator** in order to reduce disturbances to other electronic equipment in the vicinity.

offset <75kHz
Adjacent channel power (1MHz) -20 dBm
Out of band spuriouses 50 dB
Power control requirements: optional range -30 - +20 dB.

Tolerated background noise within transmission band:

Frequency offset	Max level
+/- 550 kHz	- 20 dBc
|M - N| < 2	- 20 dBm
|M - N| < 3	- 40 dBm

Tolerated background noise outside transmission band:

Frequency range	Max level
30 MHz - 1 GHz	- 36 dBm
1 GHz - 12.75 GHz	- 30 dBm
1.8 GHz - 1.9 GHz	- 47 dBm
5.15 GHz - 5.3 GHz	- 47 dBm

Figure 4.4

As can be seen from **figure 4.4** above, the RF-part of a Bluetooth-transceiver is equipped with:

1. a **passband filter**, which removes all frequencies outside the 1 MHz range which is used at the moment, for both transmission and reception
2. a **transmit-receive switch**, which connects the power amplifier to the antenna during transmission, and the LNA to the antenna during reception
3. an **LNA,** which is short for **Low-Noise Amplification.**

The specification puts some limits on the operation of the RF-part. The power supply should be between 2.7 and 5 Volts, it should be able to handle temperatures between -20 and +60 ^{o}C, and its efficiency should be at least 30% at 140 mA. The output power should also be **shut off** during reception.

One product that fills these requirements is called "MAX2240" and comes from Maxim. Two digital controlbits are used to set the VGA-step (Variable Gain Amplification) to 4 distinct levels, and this results in 4 distinct output power levels.

The antenna that are used on the **FLYWAY** vehicles has to be specially adapted for the purpose. A Swedish company, **"Intenna"** has developed and patented antennas for Bluetooth-use.

The various specifications and standards that are used:

1. **B**ased upon a small, high performance integrated radio transceiver, each of which is allocated a unique 48-bit address derived from the IEEE 802 standard.
2. **O**perate in the unrestricted **2.45GHz**

5. **O**ne-to-one connections allow maximum data transfer rate of 721 kbits/s
(3 voice channels).
6. **U**ses packet switching protocol based on frequency hop scheme with **1600 hops/s** to enable high performance in noisy radio environments. The entire available frequency spectrum is used with 79 hops of 1 Mhz bandwidth,

ISM "free band", which is available globally although slight variation of location and width of band apply.

3. **R**ange set at 10m to optimize for target market of mobile and business user.
4. **G**ross data rate 1 Mbit/s, with second generation plans to increase to 2 Mbit/s.

analogous to the IEEE 802.11 standard.

7. **L**ow power consumption drawing only **0.3 mA** in standby mode enables maximum performance longevity for battery powered devices. During data transfer the maximum current drain is **30 mA**. However, during pauses or at lower data rates the drain will be lower.

5. Bluetooth Architecture Overview

igure 5:1 provides an overview what protocols are used and supported in Bluetooth, and how they tie in together. As is usual in this kind of charts, the protocols are roughly hierarchically shown, with the "highest" protocols on top. In data communication contexts, this hierarchy means 2 things:

1. The higher protocols depend on the lower in order to exist. But the lower protocols can do without the higher, or they can support **other** protocols on the higher levels.
2. The higher protocols are usually "closer" to the user, insofar as they provide human-oriented services.

These protocols can be divided into 4 categories:

1. core protocols
2. cable replacement protocol
3. telephony control protocol
4. adopted protocols.

These 4 categories are detailed below.

Figure 5:1

1. Bluetooth core protocols

Baseband

The Baseband and Link Control layer enables the physical RF link between Bluetooth units forming a piconet. This layer controls the Bluetooth unit's synchronisation and transmission frequency hopping sequence. The two different link types defined in Bluetooth, Synchronous Connection Oriented (SCO) and Asynchronous Connectionless (ACL), are also managed by this layer. The ACL links, for data, and the SCO links, mainly for audio, can be multiplexed to use the same RF link.

Audio

Audio transmissions can be performed between one or more Bluetooth units, using many different usage models. Audio data do not

Link Manager Protocol (LMP)

LMP is responsible for link set-up between Bluetooth units. It handles the control and negotiation of packet sizes used when transmitting data. The Link Manager Protocol also handles management of power modes, power consumption, and state of a Bluetooth unit in a piconet. Finally, this layer handles generation, exchange and control of link and encryption keys for authentication and encryption.

Logical Link Control and Adaptation Protocol (L2CAP)

The Bluetooth logical link control and adaptation protocol, L2CAP, is situated over the Baseband layer and beside the Link Manager Protocol in the Bluetooth protocol stack. The L2CAP layer provides connection-oriented and connectionless data services to upper layers. The four main tasks for L2CAP are:

1. **Multiplexing:** L2CAP must support protocol multiplexing, since a

4. **Group abstraction:** The L2CAP specification supports a group abstraction that permits implementations for mapping groups on to a piconet.

An L2CAP implementation must be uncomplicated and implying low overhead since it must be compatible with the limited computational resources in a small Bluetooth unit.

Service Discovery Protocol (SDP)

SDP defines how a Bluetooth client's application shall act to discover available Bluetooth servers' services and their Bluetooth characteristics. The protocol defines how a client can search for a service based on specific attributes without the client knowing anything of the available services. The SDP provides means for the discovery of new services becoming available when the client enters an area where a Bluetooth server is operating. The SDP also provides go through the L2CAP layer but go directly, after opening a Bluetooth link and a straightforward set-up, between two Bluetooth units.

Host Controller Interface (HCI)

HCI provides a uniform interface method for accessing the Bluetooth hardware capabilities. It contains a command interface to the Baseband controller and link manager and access to hardware status. It also contains control and event registers.

number of protocols (e.g. SDP, RFCOMM and TCS Binary) can operate over L2CAP.

2. **Segmentation and Reassembly:** Data packets exceeding the Maximum Transmission Unit, MTU, must be segmented before being transmitted. This and the reverse functionality, reassemble, is performed by L2CAP.
3. **Quality of Service:** The establishment of an L2CAP connection allows the exchange of information regarding current Quality of Service for the connection between the two Bluetooth units.

functionality for detecting when a service is no longer available.

2. Cable replacement protocol

This is the **RFCOMM** protocol, whose purpose is to emulate a serial port. The protocol covers applications that use serial ports of the kind used in PC:s. Thus, RFCOMM emulates RS-232 control and data signals over the Bluetooth baseband. It provides transport capabilities for upper level services, such as OBEX.

3. Telephony control protocol

Telephony Control -Binary

The Telephony Control protocol - Binary, TCS Binary or TCS BIN, is a bitoriented protocol, which defines the call control signalling for the establishment of speech and data calls between Bluetooth units. The protocol defines the signalling for establishment and release of calls between Bluetooth units. As well as signalling to ease the handling of groups of Bluetooth units. Furthermore, TCS Binary provides functionality to exchange signalling information unrelated to ongoing calls. Establishment of a voice or data call in a point-to-point configuration as well as in a point-to-multipoint configuration is covered in this protocol (note, after establishment, the transmission is from point to point). The TCS Binary is based on the ITU-T Recommendation Q.931.

4. Adopted protocols

This section describes a number of protocols that are defined to be adopted to the Bluetooth protocol stack.

PPP

The IETF Point-to-Point Protocol (PPP) in the Bluetooth technology is designed to run over RFCOMM to accomplish point-to-point connections. PPP is a packetoriented protocol and must therefore use its serial mechanisms to convert the packet data stream into a serial data stream.

Content formats

The formats for transmitting **vCard** and **vCalendar** information are also defined in the Bluetooth specification. The formats do not define transport mechanisms but the format in which electronic business cards and personal calendar entries and scheduling information are transported. vCard and vCalendar is transferred by OBEX.

Wireless Apptication Protocol (WAP)

WAP is a wireless protocol specification that works across a variety of wide-area wireless network technologies

Telephony Control -AT Commands

A number of AT -commands are supported for transmitting control signals for telephony control. They use the serial port emulation, RFCOMM, for transmission.

TCP/UDP/IP

The TCP/UDP/IP standards are defined to operate in Bluetooth units allowing them to communicate with other units connected, for instance, to the Internet. Hence, the Bluetooth unit can act as a bridge to the Internet. The TCP/IP/PPP protocol configuration is used for all Internet Bridge usage scenarios in Bluetooth 1.0 and for OBEX in future versions. The UDP/IP/PPP configuration is available as transport for WAP.

OBEX Protocol

IrOBEX, as is the correct term, is an optional application layer protocol designed to enable units supporting infrared communication to exchange a wide variety of data and commands in a resource-sensitive standardised fashion. OBEX uses a client-server model and is independent of the transport mechanism and transport API. The OBEX protocol also defines a folder-listing object, which is used to browse the contents of folders on remote device. RFCOMM is used as the main transport layer for OBEX.

bringing the Internet to mobile devices. Bluetooth can be used like other wireless networks with regard to WAP , it can be used to provide a bearer for transporting data between the WAP Client and its adjacent WAP Server.

Furthermore, Bluetooth's ad hoc networking capability gives a WAP client unique possibilities regarding mobility compared with other WAP bearers. The traditional form of WAP communications involves a client device that communicates with a Server/Proxy device using the WAP protocols. Bluetooth is expected to provide a bearer service as specified by the WAP architecture. The WAP technology supports server push, which is used i WWW on the Internet. If this is used over Bluetooth, it opens new possibilities for distributing information to handheld devices on location basis. For example, shops can push special price offers to a WAP client when it comes within Bluetooth range. Which might be a good reason to switch off your WAP when you´re out walking.

6. How Bluetooth functions

How network connections are established

luetooth supports both point-to-point and point-to-multi-point connections. Several **piconets** (see definition above) can be established and linked together ad hoc, where each piconet is identified by a different frequency hopping sequence. All users participating on the same piconet are synchronized to this hopping sequence.

Before any connections in a piconet are created, all devices are in **STANDBY** mode. In this mode, an unconnected unit periodically "listens" for messages every 1.28 seconds. Each time a device wakes up, it listens on a set of **32 hop frequencies** defined for that unit. The number of hop frequencies varies in different geographic regions; 32 is the number for most countries.

The connection procedure for a **non-existent** piconet is initiated by **any** of the devices, which then becomes **master of the piconet thus created.**

A connection is made by a **PAGE** message being sent if the **address** is **already known,** or by an **INQUIRY** message followed by a subsequent PAGE message, if the **address** is **unknown.**

In the initial **PAGE** state, the master unit will send a train of 16 identical page messages on 16 different hop frequencies defined for the device to be paged (slave unit). If no response, the master transmits a train on the remaining 16 hop frequencies in the wake-up sequence.

The maximum delay before the master reaches the slave is twice the wakeup period (2.56 seconds) while the average delay is half the wakeup period (0.64 seconds).

The **INQUIRY** message is typically used for finding Bluetooth devices, including public printers, fax machines and similar devices with an unknown address. The INQUIRY message is very similar to the page message, but may require one additional train period to collect all the responses.

A power saving mode can be used for connected units in a piconet if no data needs to be transmitted. The master unit can put slave units into HOLD mode, where only an internal timer is running. Slave units can also demand to be put into HOLD mode. Data transfer restarts instantly when units transition out of HOLD mode. The HOLD is used when connecting several piconets or managing a low power device such as a temperature sensor.

In the **SNIFF** mode, a slave device listens to the piconet at reduced rate, thus reducing its duty cycle. The SNIFF interval is programmable and depends on the application.

In the **PARK** mode, a device is still synchronized to the piconet but does not participate in the traffic. Parked devices have given up their MAC address and only occasionally listen to the traffic of the master to re-synchronize and check on broadcast messages. It can thus receive broadcasts, but not addressed messages while parked.

Types of Links and packets

The link type defines what type of packets can be used on a particular link. The Bluetooth baseband technology supports 2 link types:

- Synchronous Connection Oriented (**SCO**) type
  (used primarily for voice).
- Asynchronous Connectionless (**ACL**) type

Error correction

There are 3 error-correction schemes defined for Bluetooth baseband controllers:

- 1/3 rate forward error correction code (FEC).
- 2/3 rate forward error correction code (FEC).
- Automatic repeat request (ARQ) scheme for data.

The purpose of the FEC scheme on the data payload is to reduce the number of retransmissions. However, (used primarily for packet data).

Different master-slave pairs of the same piconet can use different link types, and the link type may change arbitrarily during a session. Each link type supports up to sixteen different packet types. Four of these are control packets and are common for both SCO and ACL links. Both link types use a Time Division Duplex (TDD) scheme for full-duplex transmissions.

The SCO link is symmetric and typically supports time-bounded voice traffic. SCO packets are transmitted over reserved intervals. Once the connection is established, both master and slave units may send SCO packets without being polled. One SCO packet type allows both voice and data transmission - with only the data portion being retransmitted when corrupted. The ACL link is packet oriented and supports both symmetric and asymmetric traffic. The master unit controls the link bandwidth and decides how much piconet bandwidth is given to each slave, and the symmetry of the traffic. Slaves must be polled before they can transmit data. The ACL link also supports broadcast messages from the master to all slaves in the piconet.

in a reasonably error-free environment, FEC creates unnecessary overhead that reduces the throughput. Therefore, the packet definitions have been kept flexible as to whether or not to use FEC in the payload. The packet header is always protected by a 1/3 rate FEC; it contains valuable link information and should survive bit errors. An unnumbered ARQ scheme is applied in which data transmitted in one slot is directly acknowledged by the recipient in the next slot.

Software Framework

Bluetooth devices will be required to support baseline interoperability feature requirements to create a positive consumer experience. For some devices, these requirements will extend from radio module compliance and air protocols, up to application-level protocols and object exchange formats. For other devices, such as a headset, the feature requirements will be significantly less. Ensuring that any device displaying the Bluetooth "logo" interoperates with other Bluetooth devices is a goal of the Bluetooth program.

Software interoperability begins with the Bluetooth link level protocol responsible for protocol multiplexing, device and service discovery, and segmentation and

Services provided:

- Sending and receiving of data (of course!)
- Name request. The Link Manager has an efficient means to inquire and report a name or device identity up to 16 characters in length.
- Link address inquiries.
- Connection set-up.
- Authentication.
- Link mode negotiation and set-up, e.g. data or data/voice. This may be altered during the connection.
  The Link Manager decides the actual frame type on a packet-by-packet basis.
- Setting a device in sniff mode. In sniff mode, the duty cycle of the slave is reduced: it listens only every **M** slots, where **M** is negotiated at the Link manager. The master unit can only start transmission in specified time slots

reassembly. Bluetooth devices must be able to recognize each other and load the appropriate software to discover the higher level abilities each device supports. Interoperability at the application level requires identical protocol stacks. Different classes of Bluetooth devices (PC's, handhelds, headsets, cellular telephones) have different compliance requirements. More functionality would be expected from cellular phones, handheld and notebook computers. To obtain this functionality, the Bluetooth software framework will reuse existing specifications such as OBEX, Human Interface Device (HID), and TCP/IP rather than invent yet another set of new specifications.

Device compliance will require conformance to both the Bluetooth Specification and existing protocols. As far as FLYWAY is concerned, the following 3 functions would be of interest:

- Device discovery
- Peripheral communication
- Audio communication and call control

spaced at regular intervals.

- Setting a link device on hold. In hold mode, turning off the receiver for longer periods saves power. Any device can wake up the link again, with an average latency of 4 seconds. This is defined by the Link Manager and handled by the Link Controller.
- Setting a device in park mode when it does not need to participate on the channel but wants to stay synchronized. It wakes up at regular intervals to listen to the channel in order to re-synchronize with the rest of the piconet, and to check for page messages.

Authentication and Privacy

he Bluetooth baseband provides user protection and information privacy mechanisms at the physical layer. Authentication and encryption is implemented in the same way in each Bluetooth device, appropriate for the ad hoc nature of the network. Connections may require a one-way, two-way, or no authentication. Authentication is based on a challenge-response algorithm. Authentication is a key component of any Bluetooth system, allowing the user to develop a domain of trust between a personal Bluetooth device, such as allowing only the owner's notebook computer to communicate through the owner's cellular telephone. Encryption is used to protect the privacy of the connection. Bluetooth uses a stream cipher well suited for a silicon implementation with secret key lengths of 0, 40, or 64 bits. Key management is left to higher layer software.

Bluetooth´s Bandwidth

Bluetooth is not primarily meant for transferring great amounts of data. WLAN, which also uses the IEEE 802.11 standard, is better in that respect. The Bluetooth is about 720 kbit/sec. between the master and any one slave unit, after discounting the overhead. As can be seen from **figure 5:1** at right, this is sufficient for telephony, but not quite enough for video conferences and public radio. Such services, along with video and TV, would have to be provided by other means.

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Webmaster

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